BRILL

Al-Bīrūnī and Avicenna on the Existence of Void and the Plurality of Worlds

Author(s): Paul Hullmeine

Source: *Oriens*, 2019, Vol. 47, No. 1/2 (2019), pp. 114-144

Published by: Brill

Stable URL: https://www.jstor.org/stable/10.2307/26742466

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at https://about.jstor.org/terms

Brill is collaborating with JSTOR to digitize, preserve and extend access to *Oriens*

JSTOR

131.111.5.135 on Tue, 11 Jun 2024 09:03:32 +00:00

BRILL

ORIENS 47 (2019) 114–144

ORIENS
brill.com/orie

Al-Bīrūnī and Avicenna on the Existence of Void and the Plurality of Worlds

Paul Hullmeine
Bavarian Academy of Sciences and Humanities, Munich
phullmeine@ptolemaeus.badw.de

Abstract

The present paper is devoted to the famous letter exchange between al-Bīrūnī and Avicenna. Its main concern is to elaborate the philosophical content of two of the 18 questions, namely on the existence of void and the plurality of worlds. Since this has previously only been done in a superficial way, this paper aims to draw attention to al-Bīrūnī's hitherto unknown philosophical doctrines. In the course of this investigation, it will be necessary to consider his arguments from the letters in view of the background of the ancient, Neoplatonic, and Arabic philosophical and theological discourse. Since this letter exchange is dated to the beginning of Avicenna's career, his answers illuminate the development of his thought.

Keywords

Avicenna – al-Bīrūnī – Arabic philosophy – void – plurality of worlds

1 Introduction

Avicenna and Abū r-Rayḥān al-Bīrūnī are two of the most important figures of the Islamic world in their fields, which are medicine and philosophy or astronomy respectively. Despite the availability of extensive manuscript material, as well as two editions of the correspondence, relatively little work has been done on these letters.[1] This may explain why al-Bīrūnī's evaluations of philosophical

---

[1] For a list of the manuscripts, cf. Boris A. Rosenfeld and Ekmeleddin Ihsanoğlu, *Mathemati-*

© KONINKLIJKE BRILL NV, LEIDEN, 2019 | DOI:10.1163/18778372-04701002

questions remain underdeveloped. This paper makes a start on this important task. The correspondence with Avicenna is the only extant work by al-Bīrūnī dedicated to philosophical problems, and consists of 18 questions. The first ten are based on Aristotle's *De caelo*, while the other eight deal generally with problems in physics. After each question, we find Avicenna's answer (*ǧawāb*). In most cases, however, al-Bīrūnī is not satisfied with the answers he receives, and therefore writes replies (*iʿtirāḍāt*). In the end, Avicenna delegates the task of answering al-Bīrūnī for the second time to his pupil al-Maʿṣūmī (d. 1029 AD). A remark at the beginning of the text informs us that the letters were sent from Ḫwārizm, that the answers were delayed, and that Avicenna rewrote al-Bīrūnī's questions "in his own words" (*bi-lafẓika*), probably to remind al-Bīrūnī of what he had asked him. Finally, al-Maʿṣūmī writes in the introduction of his answers that he decided to rewrite the answers, which were already sent to al-Bīrūnī by someone named Abū l-Qāsim but got lost.[2] Therefore, there seems to have been a version of answers that is now lost, such that al-Maʿṣūmī elaborated only on a copy of these answers. We can infer from these reports that the text we have now was part of a real exchange of letters, compiled in Avicenna's environment around 1000 AD, and that we do not have the original questions by al-Bīrūnī.[3] His questions are related to various parts of Aristotelian

---

cians, Astronomers, and other Scholars of Islamic Civilization and their Works (*7th–19th c.*) (Istanbul: Research Center for Islamic History, Art and Culture, 2003), 126 (s.v. "PHI"). The main edition, which is used as reference in this paper, is provided by Seyyed Hossein Nasr and Mahdi Mohaghegh, *al-As'ilah wa'l-Ajwibah* (*Questions and Answers*). *Including the further answers of al-Bīrūnī and al-Maʿsūmī's defense of Ibn Sīnā* (Tehran: High Council of Culture and Art, 1973). In addition, cf. the sometimes better, but incomplete edition by Muhammed Tancî, "Beyrunî'nin Ibn-i Sinâ'ya Yönelttiği Bazı Sorular, Ibn-i Sinâ'nın Cevapları ve Bu Cevaplara Beyrunî'nin Itirazları," in *Beyrunî'ye Armağan* (Ankara: Türk Tarih Kurumu Basımevi, 1974), 231–301. Some partial investigations of the philosophical content of the questions can be found in Alessandro Bausani, "Some Considerations on Three Problems of the Anti-Aristotelian Controversy between al-Biruni and Ibn Sina," in *Akten des VII. Kongresses für Arabistik und Islamwissenschaft*, ed. by Albert Dietrich (Göttingen: Vandenhoeck & Ruprecht, 1976), 74–85, and in the pioneering work: Seyyed Hossein Nasr, *An Introduction to Islamic Cosmological Doctrines*, revised edition (Albany: Thames and Hudson, 1993), 107–76. Strohmaier offers a summary of every question in Gotthard Strohmaier, *Avicenna* (Munich: C.H. Beck, 2006), 43–56. Finally, there is a complete English translation without commentary by Rafik Berjak and Muzaffar Iqbal. Cf. Rafik Berjak and Muzaffar Iqbal, "Ibn Sīnā—Al-Bīrūnī Correspondence," *Islam & Science* 1–5 (2003–07), published in eight parts. However, I offer my own translation in this article.

[2] Cf. Ibn Sīnā and al-Bīrūnī, *As'ila*, 2,2–4 and 59,5–60,1. There is no mention of this intermediate step in the *Tatimmat* by al-Bayhaqī, cf. the English translation in Max Meyerhof, "'Ali al-Bayhaqī's Tatimmat Siwān al-Hikma: A Biographical Work on Learned Men of the Islam," *Osiris* 8 (1948): 122–217, esp. 163 f.

[3] For the dating cf. Gotthard Strohmaier, *Al-Bīrūnī. In den Gärten der Wissenschaft: Ausgewählte*

philosophy. However, there is one question which apparently was of particular interest to al-Bīrūnī since he refers to it frequently in the exchange. This is the question of the existence of void, and since this was widely discussed from the Pre-Socratics to the Muʿtazilites, it is suitable to illustrate the various influences on the exchange and on both of the interlocutors. Strongly connected to this issue is the question of the plurality of worlds, which is also raised by al-Bīrūnī in a question against the Peripatetic doctrine. In addition to granting an insight into al-Bīrūnī's philosophical positions, this correspondence includes testimony from an early stage of Avicenna's career. Thus, another interesting outcome of this investigation will be a comparison to his later (main) works.

2 Existence of Void in al-Bīrūnī's *Chronology*

Before we investigate the details of the correspondence, we should note that there is a passage from another work by al-Bīrūnī that has already been cited in modern literature as evidence of al-Bīrūnī's attitude towards the existence of void. The passage in question is from his voluminous work *Chronology of Ancient Nations*, as it was called by Eduard Sachau in his translation of the entire work.[4] Though it is not a philosophical work per se, this book is full of digressions on a wide range of topics.[5] One of these digressions includes a discussion of void, or more precisely, on the functioning of the clepsydra. Seyyed Hossein Nasr first drew attention to this passage, taking al-Bīrūnī to be arguing

---

Texte aus den Werken des muslimischen Universalgelehrten, 2nd edition (Leipzig: Reclam, 2002), 17, and Dimitri Gutas, *Avicenna and the Aristotelian Tradition: Introduction to Reading Avicenna's Philosophical Works*, 2nd edition (Leiden, Boston: Brill, 2014), 449. In the latter, one can find a detailed chronological bibliography of Avicenna. There is copious secondary literature on al-Bīrūnī's astronomical works, which is not necessary to cite here. For an overview of his life and works, cf. Jacques-Dominique Boilot, "L'oeuvre d'al-Beruni. Essai Bibliographique," *Mélanges de l'Institut dominicain d'études orientales* 2 (1955): 161–396, J.S. Mishra, "New Light on Albiruni's Stay and Travel in India," *Central Asiatic Journal* 15 (1972): 302–12, Nasr, *Introduction*, 109–15, Strohmaier, *In den Gärten*, 9–31, Mario Kozah, *The Birth of Indology as an Islamic Science: Al-Biruni's Treatise on Yoga Psychology* (Leiden: Brill, 2016), 7–10.

[4] al-Bīrūnī, *Kitāb al-Āṯār al-bāqiyya ʿan al-qurūn al-ḫāliyya*, ed. by Eduard Sachau (Leipzig: Brockhaus, 1878), and transl. into English by Eduard Sachau (London: William H. Allen and Co., 1879).

[5] As al-Bīrūnī himself puts it: "If I plunge into subjects foreign to the plan of this book, it is only for the purpose of leading the reader, as it were, about in the garden of wisdom, so as to prevent his mind and eye becoming weary and getting a dislike (to continue the reading of this book)." Cf. al-Bīrūnī, *al-Āṯār*, 185, 3 f. (transl. by Sachau, 167).

in it against the existence of void.[6] However, a closer look into the text reveals that this is not the case. The main question al-Bīrūnī addresses here is the natural movement of water and its direction. He recounts discussions with people who thought that water moves horizontally or with a slight inclination. After defending the Aristotelian doctrine that water tends to the earth's centre, he admits there may be some cases where water indeed rises and he goes on to explain why this is so. This is the point in his discussion where the clepsydra and its function are explained. Al-Bīrūnī writes:

> An illustration of this principle is the instrument called **Water-thief** (clepsydra).[7] For if you fill it with water and put both its ends into two vessels, in both of which the water reaches to the same level, then the water in the clepsydra stands still even for a long time, not flowing off into either of the two vessels. For the one is not preferable to the other, and it is impossible that the water should flow off equally into both vessels, for in that case the instrument would get empty (*taḫlū*). —**Now, void (*wa-l-ḫalāʾ*) is either not existent, as some philosophers suppose, or it is existent and attracts bodies, as others believe. If, now, its existence is impossible, it does not exist (*fa-iḏā kāna mumtaniʿ al-wuǧūd lam yūǧad*), or if it is something which attracts bodies, it keeps back the water and does not let it flow off, unless its place be occupied by some other body.**—[8] But if you then (*ṯumma*) place the sides a little lower [than the other], the water flows immediately off into that direction.[9]

The experiment itself should be quite clear. Although the natural movement of water is directed towards the earth's centre such that the water should flow out of the pipe, this is not the case when we immerse both ends of the pipe into two vessels that are filled with water. Since the surface level of the water is the same, the water simply remains in the pipe. Because of this observation, one could argue against Aristotle and al-Bīrūnī that water does not naturally flow downwards. Of course, al-Bīrūnī does not give us possible counter-examples without proposing a solid solution. This solution depends upon the existence or non-existence of void. Indeed, the reason for this somewhat strange observation is the fact that the pipe cannot become empty. Al-Bīrūnī then goes on to give a more detailed explanation of why this should not be the case, and starts by distinguishing two opposed attitudes towards the existence of void. There are some philosophers (*falāsifa*), he says, who argue against the existence of void, and others who believe that it is both possible *and* has the ability to attract bodies. This formulation is interesting in itself since we find a similar account in Avicenna's *Kitāb aš-Šifāʾ* and in Faḫr ad-Dīn ar-Rāzī's *al-Mabāḥiṯ al-mašriqiyya*. The latter reports that the doctrine of the existence of void and its attractive power was upheld by Abū Bakr ar-Rāzī.[10] From the fact that al-Bīrūnī wrote a biography of Abū Bakr ar-Rāzī and composed a list of his works, we can assume that al-Bīrūnī probably had Abū Bakr ar-Rāzī in mind, as well.[11] He may also have in mind the Muʿtazilite tradition in Baṣra where the existence of void was defended by *kalām*-thinkers such as Abū Hāšim al-Ǧubbāʾī (d. 933 AD). On the other side of this controversy were both the Muʿtazilites from Baġdād who despite espousing an atomist position argued against the possible existence of void, and al-Fārābī from the *falsafa*-tradition whose epistle on void will be treated below.[12] Of course, the most important authority in this debate was unsurprisingly Aristotle.

---

[6] Cf. Nasr, *Introduction*, 126. Anton M. Heinen later supported his view, cf. Anton M. Heinen, "A Priori Positions Determining al-Biruni's Scientific Work," in *The Scholar and the Saint: Studies in Commemoration of Abu'l-Rayhan al-Bīrūnī and Jalal al-Din al-Rūmī*, ed. by Peter J. Chelkowski (New York: University Press, 1975), 54–6.

[7] The original clepsydra was not shaped such that both its ends could have been immersed into two vessels as described in this passage. The device in this case rather seems to be a pipe.

[8] The dashes are my own additions. They are supposed to indicate the beginning and end of the so-called "*ḥāl*-clause" in the Arabic text. This then is further evidence for my reading that this explanation on void is not supposed to be part of the main argumentation of the passage, i.e. that the question of the existence or non-existence of void is not at stake here.

[9] al-Bīrūnī, *al-Āṯār*, 262,22–263,6, English transl. by Sachau, 253 f., modified.

This then is the historical situation of the question of void at the time of al-Bīrūnī, and, as evidenced in his subsequent correspondence with Avicenna, al-Bīrūnī is versed in the details of this debate. But in this passage from the *Chronology*, he does not critically engage with the different arguments. Rather, he describes how both camps would explain what happens in the clepsydra. For the opponents of the void, he simply explains that since void's existence is impossible, it is also impossible for the pipe to become empty lest a void be produced. According to the defenders of the void, the attractive power of void is responsible for keeping the water in the pipe. Al-Bīrūnī does not offer an indication of his own preference for one or the other possible explanation. Rather, in what follows he continues with his original investigation into the direction of the movement of water. He describes how, once one of the vessels is lifted, the water starts to flow through the pipe into the lower vessel, letting us finally see the natural downward motion of water.

---

[10] This was already pointed out by Shlomo Pines, *Beiträge zur islamischen Atomenlehre* (Berlin: A. Heine, 1936), 47, fn. 1.

[11] The biography was edited by Paul Kraus, cf. Paul Kraus (ed.), *Épître de Bērūnī, contenant le répertoire des ouvrages de Muḥammad B. Zakarīyā ar-Rāzī* (Paris: Impr. Orientaliste au Calame, 1936). For a German translation, see Julius Ruska, "Al-Biruni als Quelle für das Leben und die Schriften al-Razi's," *Isis* 5 (1923): 26–50. Avicenna refers to Abū Bakr ar-Rāzī in another question, i.e. on the eternity of the world, and accuses al-Bīrūnī of being influenced by him. Cf. Ibn Sīnā and al-Bīrūnī, *As'ila*, 13,10 f.

[12] For the discussion within *kalām*, cf. Alnoor Dhanani, *The Physical Theory of Kalām: Atoms, Space, and Void in Basrian Muʿtazilī Cosmology* (Leiden: Brill, 1994), 79–80. I give textual evidence for the various thinkers when I analyse their arguments in particular.

3 Existence of Void in the Correspondence

It seems clear that we cannot derive al-Bīrūnī's personal commitments regarding the (non-)existence of void from this passage alone, despite attempts to do so in previous scholarship.[13] His concern here is the natural movement of water and he endeavours to explain why water can be suspended in a clepsydra or pipe. Since this is the point of his digression, he tries to explain this observation regardless of whether his reader is a defender or an opponent of the existence of void. Such an interpretation does not shed light on his own commitments. Luckily, this is not the only passage in which al-Bīrūnī refers to the void. As promised, we can now turn to the correspondence between al-Bīrūnī and his contemporary Avicenna. Four of these 18 questions address the problem of whether or not the existence of void is impossible. The frequency of its appearance evidences this question's centrality to al-Bīrūnī's engagement with the Aristotelian corpus. Though it is not the first mention of void in the correspondence, the **sixth question on physical problems** serves as a suitable starting point for this investigation. As in the passage from the *Chronology*, the first question I want to draw attention to concerns a physical experiment:

> If we agree that there is no void, either within our world or outside of it, why does water ascend into a vessel, which is sucked out and turned around into water?[14]

---

[13] Cf. fn. 6 above.

[14] Ibn Sīnā and al-Bīrūnī, *As'ila*, 47,5–7. Berjak and Iqbal, "Correspondence," part 4 (2004): 186, translate "*ilā āḫir al-faṣl*" at the end of the question as "[water rises up in it] to the end of its limit," as if it belongs to al-Bīrūnī's question. However, this is a usual phrase in these letters to indicate that al-Bīrūnī's orginal question was shortened within Avicenna's circle. See also the seventh question on physical problems, *As'ila*, 48,10–11.

The way in which al-Bīrūnī asks his question is not as innocent as it might seem at first sight. It is quite obvious that he only concedes the premise, namely that void is impossible, for the sake of the argument. He wants to know how Avicenna (or any Peripatetic) would explain this phenomenon without the void. So, though directly attacking neither the general negation of void nor specific arguments against its existence, he challenges the coherence of such a commitment. At this point in the text, he does not elaborate upon potential arguments that could be used to address the problem.

The experiment itself is very simple and can be done with bottles at home: One first sucks air out of the bottle and quickly submerges it upside-down in water. One can then see that a small amount of water rises into the bottle. The obvious question arises: Into which space does the water go? And why did the water move against its natural direction? A longstanding debate concerning the proper interpretation of this experiment frames the dispute between defenders and opponents of void. This debate can be traced to the ancient Pneumatics (e.g. Hero of Alexandria), and we find it widely discussed again within the Muʿtazila, as it has been in the case of the clepsydra.[15] As Hans Daiber has pointed out, al-Fārābī had this background in mind when he wrote his *Risāla fī l-ḫalāʾ*.[16] This short work itself is not a refutation of all the various arguments for the existence of void, but rather deals only with this experiment. Since his explanation will be interesting for us when we look at Avicenna's answer to al-Bīrūnī, let us briefly examine the train of thought here. After he proves that air is bodily, he goes on to elaborate on its expansion and contraction. He cites as an example air's change in density through a change in temperature, and tries to show that in these cases a body can indeed expand or contract without addition or subtraction of parts.[17] In the present experiment, there is no change in temperature, but rather the sucking movement responsible for the rarefaction of the air-parts in the flask. We forcibly suck air out of the flask, but the air inside still fills the whole content of the flask and therefore rarefies and expands. When we then stop sucking, the air returns to its normal state (of density).[18] For al-Fārābī it is clear that the sucking leads to a forced rarefaction of the air. This is then the reason why the air contracts when we stop sucking and invert it into the water. It is important to note here that al-Fārābī denies a so-called attractive force of the void, which pulls the water upwards into the flask.[19] Rather, the contact between the water and the air leads to the observation that the air brings water with it into the flask.[20]

---

[15] Cf. the detailed presentation in Hans Daiber, "Farabis Abhandlung über das Vakuum," *Der Islam* 60 (1983): 37–47 and Dhanani, *The Physical Theory*, 78 and 86, and especially for Hero Vaios Argyrakis, "The clepsydra experiment, clepsydra's functioning and the related devices in Heron's *Pneumatics*," *Almagest* 2 (2011): 16–27.

[16] Edited under the title *Ebû Nasr Il-Fârâbî'nin Halâ Üzerine Makalesi. Fârâbî's Article On Vacuum*, ed. and transl. by Necati Lugal and Aydın Sayılı (Ankara: Türk Tarih Kurumu Basımevi, 1951), afterwards shortly *Fī l-ḫalāʾ*.

[17] Al-Fārābī, *Fī l-ḫalāʾ*, 32.

[18] Al-Fārābī, *Fī l-ḫalāʾ*, 33. Cf. the Aristotelian background at *Phys.* IV.8, 215a1f.

Al-Bīrūnī is surely aware of the role this experiment had played already in the preceding discussions.[21] Al-Bīrūnī was not the first thinker to use practical examples and observations to challenge specific Peripatetic doctrines. A good indication for this is the fact that al-Fārābī based his defence of the nonexistence of void on precisely this experiment. When al-Bīrūnī poses this question again to Avicenna, not even a century after al-Fārābī's strictly Aristotelian explanation of this observation, one might expect Avicenna to rehearse an argument similar to al-Fārābī's. But, surprisingly, he offers another explanation:

> This is not because of the void, for the cause of this is the following, namely that if you suck out the flask and if it is impossible that air comes out of it—for void is impossible—then the sucking stimulates the air in the flask to [other] successive forced movements which are generating heat and warmth, whereas the heat originates an inflation. When the air of the flask inflates, it needs more space. It is necessary that a part of it streams out[22] and [the part] which the flask can accommodate remains [in the flask]. When the cold of the water encounters [this part in the vessel], [the air] gets denser and contracts and takes less space. The existence of void being impossible, water enters the flask in proportion to the contraction that is originated for the inflated air by the contact with the cold body. Don't you see that if you don't suck, but do the opposite, i.e. blowing, and if you blow into the flask and don't stop until the movements of

---

[19] He had argued in the beginning against such a force, cf. al-Fārābī, *Fī l-ḫalāʾ*, 29.

[20] Al-Fārābī, *Fī l-ḫalāʾ*, 35.

[21] As Daiber, "Farabis Abhandlung," 44, fn. 45 points out, the *Pneumatica* of Philo of Byzantium for example have been translated into Arabic and Hero was known at least by name. A possible influence by the Pneumatics on John Philoponus (cf. Sylvia Berryman, *The Mechanical Hypothesis in Ancient Greek Natural Philosophy* (Cambridge: University Press, 2009), 191–93) and on Abū Bakr ar-Rāzī (cf. Pines, *Beiträge*, 47 f., fn. 1), two very important sources for al-Bīrūnī, has also been suggested.

[22] The Arabic word is *yaḫruǧ*. This may be confusing, since it already happened through the fact that one had sucked out the air in the beginning. An explanation might be that Avicenna considers this to be the same experiment as if one heated the flask (as he writes at the end of his answer). Therefore, he uses the same argumentation here, without adapting the details of his argument.

> the blowing heat the air in the flask and then hold it into the water—then you have done the same and this has [already] been tried. Likewise you do the same, if you heat the flask. This is enough for the answer.[23]

In his answer, Avicenna builds on the premise that al-Bīrūnī granted for the sake of argument. Since void is impossible, other procedures have to happen in the flask. Here, Avicenna departs from al-Fārābī. Avicenna claims that the air in the flask is heated due to forced movements caused by sucking and therefore expands. When this hot air then encounters the cold water, there is another change in temperature which leads to the contraction of the air. It seems to be the case for Avicenna, as it is for al-Fārābī, that the contact between the surfaces of the water and the air is responsible for the observation that water rises upwards into the flask (although he does not say so explicitly). In another respect, however, he is in disagreement with al-Fārābī. For al-Fārābī the change in temperature was only one possible explanation for the contraction and expansion of bodies. But for Avicenna, this change in temperature is the main explanation of what occurs in the flask, and it is the reason for the expansion and contraction of the air.

At first sight, Avicenna's account may seem to be very close to al-Fārābī's explanation, since both include change in "density." However, the gap between the two explanations becomes more evident when we look at Avicenna's remarks at the end of his answer, namely his claim that one can blow air into the flask or heat the flask, as well, instead of sucking air out of it. In either case, the same result obtains. However, Avicenna subsequently gives a different account. In the physical part of his *Kitāb aš-Šifāʾ*,[24] after leading the reader through the different (Peripatetic) arguments against void in II.8, he returns again to the same experiment. Here we find Avicenna arguing along different lines. This new argument depends upon the notion of place (*makān*). Place for Avicenna, as it is for Aristotle, is the inner surface of the containing body. This place is dependent on the body that exists together with the place as well as the containing body. We clearly see that, in this passage, Avicenna is building upon this notion of place. A portion of the air leaves the flask through the outer force, but the rest, which remains in the flask, is kept back by the inner surface of the flask, i.e. the containing body. The reason that a void space cannot occur, is the adhesion of air's surface and of the flask's inner surface. The rising of the water into the flask can be explained easily in accordance with the conclusion that al-Fārābī had previously argued for, namely that the air, which is rarefied through the fact that it tries to adhere to the inner surface of the flask, returns to its original state once the sucking movement ceases.[25]

---

[23] Ibn Sīnā and al-Bīrūnī, *Asʾila*, 47,8–48,7.

[24] Hereafter called *as-Samāʿ aṭ-ṭabīʿī*, cited according to the English-Arabic text offered in Ibn Sīnā, *The Physics of the Healing: A parallel English-Arabic text translated, introduced, and annotated by Jon McGinnis* (Provo, Utah: Brigham Young University Press, 2009).

As seen above, in the correspondence, Avicenna argued that the change in temperature was responsible for the change in density; in his *as-Samāʿ aṭ-ṭabīʿī*, however, he seems to adopt al-Fārābī's mode of argumentation. This could suggest a possible development in Avicenna's thought, at least with respect to these arguments for the existence of void. Another instance can also be drawn from the letter exchange with al-Bīrūnī. The argument, discussed above in relation to his notion of place, is only applied to the experiment of removing air from a flask. In his *as-Samāʿ aṭ-ṭabīʿī*, he seems to reconsider his claim, contained in the answer to al-Bīrūnī, that one could blow air into the flask or heat it to produce the same phenomenon with the same explanation. Here, the argument from the change in temperature reappears, and Avicenna uses it to explain the appearance of air bubbles at the surface of water (he uses the verb *yubaqbiq*).[26] In short, Avicenna divides his argument from the correspondence: The argument from place and change in density accompanies the experiment when we suck air out of the flask, and the argument from the change in temperature is now referred to the experiment when we heat the flask. His short comment on the appearance of air bubbles on the surface of the water leads us to al-Bīrūnī's reply to Avicenna's answer. There, we find a similar description of what happens when we heat the flask instead of sucking air out of it:

> You only established proofs for the defenders of the void, because if there occurs an inflation in the air through sucking, like you said, and air leaves the flask, what it cannot hold [any more], where does it go if there is no void in the world? Unless someone claims that all at once, an equal amount of air is pushed back in the world, so that it contracts and [this] contraction and the inflation are in balance. Regarding what you said, that such [an experiment] has been tried, I have tried it [myself]. What happened is the opposite, namely that air came bulging (*taqabqub*) out of the flask, and no water entered [the flask].[27]

To start with the last remark of his reply, it is very interesting that al-Bīrūnī points out to Avicenna that it may not be the case that all three possible ways to do this experiment lead to the same result. In addition, al-Bīrūnī seems to speak, as well, of air bubbles when we heat the flask before submerging it.[28] For al-Bīrūnī, the appearance of bubbles is of particular interest, since this appearance raises the question of why these bubbles do not appear when one simply sucks air out of the flask. This was an argument used by the Baṣrian Muʿtazilites, since it could indicate that the water, while rising into the flask, enters emptied space.[29]

---

[25] Cf. Ibn Sīnā, *as-Samāʿ aṭ-ṭabīʿī*, II.9.20.

[26] Cf. Ibn Sīnā, *as-Samāʿ aṭ-ṭabīʿī*, II.9.21.

[27] Ibn Sīnā and al-Bīrūnī, *Asʾila*, 58,4–10.

In the following, we shall focus now on a part of al-Bīrūnī's reply that is of particular interest from a philosophical point of view. His question of where the air that leaves the flask could go to if there were no empty space frequently grounded arguments for the existence of void in both ancient atomist and Muʿtazilite discussions. The claim that there cannot be movement without the acceptance of void spaces in which a body can move into is already reported by Aristotle.[30] He refutes this argument by employing his conception of *antiperistasis* with regard to locomotion, along with his account of different states of density (*manon* and *pyknon*).[31] With respect to this issue, therefore, al-Bīrūnī sides with the ancient atomists and the Baṣrian Muʿtazilites against the peripatetic arguments. This suggests, at minimum, that al-Bīrūnī is not satisfied by the arguments that have been set forth against void's existence. Furthermore, it could suggest that al-Bīrūnī is convinced by the atomists' arguments for the existence of void. As such, we may consider al-Bīrūnī to be a defender of the void. Al-Bīrūnī sees two possible ways to make contraction and expansion of bodies in a world possible. First, empty spaces must exist. Otherwise, expansion and contraction must occur simultaneously and proportionally.[32] The latter is introduced merely as a possibility, and should be considered as a *reductio ad absurdum*. Thus, al-Bīrūnī suggests that if we reject the existence of void, then someone must prove that an equivalent contraction *always* accompanies an expansion. The **tenth question regarding *De caelo*** evidences al-Bīrūnī's belief that this point is impossible to prove. In this question, he wonders whether elements when they change qualitatively really become another element.[33] He takes as examples the evaporation of water:

---

[28] Although al-Bīrūnī calls this *taqabqub*, which literally means something like "to bulge." However, this probably refers to the observation that air bulges from the surface of the water.

[29] Cf. Dhanani, *The Physical Theory*, 85. Additionally, this passage gives us another instance for a development in Avicenna's thought. He seems to adopt al-Bīrūnī's criticism from the letters in his later written *as-Samāʿ aṭ-ṭabīʿī*. Another possible influence is already described by Dag Nikolaus Hasse regarding the nature of light. Cf. Dag Nikolaus Hasse, *Avicenna's* De anima *in the Latin West* (London: Warburg Institute, 2000), 108–13.

[30] *Phys*. IV.6, 213b4–15. For a detailed discussion of his arguments, that there cannot be movement into void spaces, cf. Richard Sorabji, *Matter, Space and Motion: Theories in Antiquity and Their Sequel* (London: Duckworth, 1988), ch. 9, and David Furley, *Cosmic Problems: Essays on Greek and Roman Philosophy of Nature* (Cambridge: University Press, 1989), ch. 7. Avicenna touches on this discussion only shortly in his *as-Samāʿ aṭ-ṭabīʿī* at two passages (II.6.12 and 9.17).

[31] *Phys*. IV.7, 214a26–32 and IV.8, 215a14–17 regarding his theory of *antiperistatis*, and IV.9, 216b22–30 regarding his account of change in density through, for example, qualitative change.

> [Regarding] the transformations of things into each other: Does this [happen] in the way of proximity (*taǧāwur*) and interpenetrating or in the way of change?[34] Let us take the air and the water as an example. When water turns into an airy state, does it really become air or do the [water-] parts disperse among [the air-parts], so that it becomes invisible and one cannot see the dispersed parts?[35]

Here, again, al-Bīrūnī was not the first one in the Arabic tradition to question Aristotle's doctrine of the qualitative change of elements.[36] But the focus of the question is changed by Avicenna's answer. He probably anticipates the possible link between an atomistic system and the vaporisation of small water parts into empty space within the air. This may be in the background of his answer and the reason he appeals to the void:

---

[32] At *Phys.* 216b22–30, Aristotle analyzes the arguments for the existence of void: If there were no void, then there would be (a) either no movement at all, or (b) the world would have to bulge and throw waves, or (c) the change of masses would have to occur simultaneously and proportionally. Al-Bīrūnī does not mention options (a) and (b), but only refers here to (c). This is interestingly similar to the account of John Philoponus: He divides the statements into two different sets of arguments. First, if there were no loose and dense, then there would be (a) or (b). But because this has to be rejected, there are two possible ways to explain the existence of loose and dense, namely (c) and the existence of void. And since (c) is "fanciful" (*plasmatōdes*), void has to exist (of course, this is how Philoponus reads Aristotle's account of the Atomists' argument for void). Cf. Philoponus, *In Aristotelis physicorum libros quinque posteriores commentaria*, ed. by Girolamo Vitelli, CAG, vol. 17 (Berlin, 1888), 672,8–17.

[33] Aristotle argued in various passages that elements may change into one another, e.g. *De caelo* III.6, 304b23–305a14, *De Gen.* II.1 and 4, *Meteor.* I.3, 339a36–b2.

[34] Berjak and Iqbal, "Ibn Sīnā—al-Bīrūnī Correspondence," part 3 (2004):61, translate as follows: "Is it the result of their proximity or intermingling or some other process?" I agree with their translation, insofar as I also adopted the reading *taǧāwur* instead of *taǧāwuz*, which is printed in the edition. However, *taǧāwuz*, perhaps in the sense of "passing into one another," might also work. I thank the anonymous reviewer of the first draft of this article, who called my attention to this problem, and Peter Adamson for advice.

[35] Ibn Sīnā and al-Bīrūnī, *As'ila*, 34,10–14.

[36] Since this is not the question I want to mainly address in this paper, it shall suffice to name an-Naẓẓām as example who is known for his own theory of mixture. Cf. Josef van Ess, *Theologie und Gesellschaft im 2. und 3. Jahrhundert Hidschra: Eine Geschichte des religiösen Denkens im frühen Islam*, vol. III (Berlin: De Gruyter, 1991–97), 335–42 and 363–4.

> The increase of bodies in quantity [happens] like the following: We fill a flask with water, seal its neck and heat it, then the flask breaks because the water-parts turn into air and increase along their dimensions and so need more space. This is either because void is mixed into the water parts, or the reason for [this] change is not the dispersal of the parts. But the existence of void is impossible, so it is necessary that the second case is true, i.e. that the reason for [this] change is not the dispersal of the parts. Rather, [the reason for this change] is that the matter (*al-hayūlā*) takes another form.[37]

As Avicenna tries to show with his experiment, the water in the flask really becomes air and therefore expands. This is a classic Peripatetic argumentation, connecting Aristotle's doctrine of the non-existence of void and the change in density through elemental change.[38] It is not difficult at this point to imagine al-Bīrūnī's reply. He appeals to the same argument we have already seen before. He claims that Avicenna must show that a comparable contraction takes place in order to make space for the expansion of the air.[39] If Avicenna cannot show this, then Avicenna's answer fails to be a solid demonstration against the existence of void, at least in al-Bīrūnī's opinion.

To this point, al-Bīrūnī has argued against the impossibility of void by appealing to an argument, which was already ascribed to the ancient atomists, and to an experiment, which was heavily debated in 9th and 10th century *kalām* and by al-Fārābī. An additional argument, which has already been known to Aristotle, appears in the **ninth question on *De caelo***. As in the question treated above, al-Bīrūnī does not ask explicitly about the existence of void. Instead, he wonders how the earth is heated, given that fire tends to move away from the centre of the world. Further, he adds the question of whether the rays of the sun are bodily or accidents or something else.[40] Avicenna argues in his reply that, firstly, the air around the earth is heated through the reflection of the rays from the earth,[41] and secondly, that the rays cannot be bodies since, if they were bodies, there would be two bodies in one place, namely air and the rays.[42] Al-Bīrūnī criticizes this account in his reply:

---

[37] Ibn Sīnā and al-Bīrūnī, *As'ila*, 35,8–36,1.

[38] *Phys.* IV.7, 214a32–b3.

[39] Ibn Sīnā and al-Bīrūnī, *As'ila*, 55,17–56,3. And remember: This is what Philoponus called "fanciful," see above fn. 32.

[40] Ibn Sīnā and al-Bīrūnī, *As'ila*, 33,6–8. Cf. the Aristotelian background on the motion of the elements at *De caelo* IV.4, 311a16–21 and 311b13–29. The problem of how the earth is heated

> How does what you say follow necessarily? Someone who claims that a ray of the sun is a body, either affirms the [existence of] void, so then your argument is not valid for him; or he claims that the ray of the sun eternally exists in the sphere together with the existence of air in [the sphere]. But why don't you claim that water is not a body? For if it were a body, then there would be two bodies in one place, I mean [for example] water and dust in the clay.[43]

That Avicenna uses the impossibility of two bodies being in one place as an argument to prove that the rays are not bodies is, for al-Bīrūnī, a welcome invitation to return to the question of void. He writes that one could argue along the same lines to prove that water is not bodily. As an example, he refers to water and dust coming together and forming clay. This recalls a similar argument that is ascribed to Leucippus and can be found in Aristotle's *Physics*.[44] This argument concludes that there must be void spaces within bodies, since one vessel completely filled with ashes can accommodate the content of another vessel

---

is discussed in *Meteor*. I.3, 340a17–341a31. On the reception in Late Antiquity and the Arabic tradition, cf. Paul Lettinck, *Aristotle's Meteorology and its Reception in the Arab World: With an Edition and Translation of Ibn Suwār's Treatise on Meteorological Phenomena and Ibn Bajja's Commentary on the Meteorology* (Leiden, Boston, Cologne: Brill, 1999), 16–7, 37, 41–44, 56.

[41] In *al-Āṯār*, 256–7 (cf. the English translation by Sachau, 247), al-Bīrūnī writes that the reason for the heat of the rays is not their reflection. But shortly after, he refers to his discussion with the "young" Avicenna and gives his explanation that earth is heated due to the reflection of the rays of the sun as a possible solution.

[42] Ibn Sīnā and al-Bīrūnī, *As'ila*, 33,9–34,9. He refers to the second book of *De anima* and to the *De sensu* and probably has *De anima* II.7, 418b4–18 and *De sensu* 439a16–b1 in mind. Cf. Ruth Glasner, "The Hebrew Version of *De celo et mundo* Attributed to Ibn Sīnā," *Arabic Sciences and Philosophy* 6 (1996): 103. Interestingly, Simplicius as well connects the Aristotelian description of the rays as non-bodily with the theory that the earth is heated by the reflection of the rays of the sun. Cf. Simplicius, *In Aristotelis de caelo commentaria*, ed. by Johan L. Heiberg, CAG, vol. 7 (Berlin: Georg Reimer, 1894), 441,2–31 (at least, if one accepts the change from *somatikas* to *asomatikas* in the Greek text suggested by Ian Mueller in his translation, *Simplicius: On Aristotle On the Heavens* (Ythaca, New York: Cornell University Press, 2004), cf. fn. 381).

[43] Ibn Sīnā and al-Bīrūnī, *As'ila*, 54,17–55,3.

[44] *Phys*. IV.7, 214b3–10.

completely filled with water. Clearly, al-Bīrūnī's gesture towards this observation should be considered as a *reductio ad absurdum* intended to challenge Avicenna's claim that the rays of the sun are not bodies. Thus, it seems to be the case that al-Bīrūnī considers the rays to be bodies. Unfortunately, he does not indicate a preference for one account over the other in this passage.[45] However, his renewed appeals to the existence of the void, as well as dependence upon ancient atomist arguments, suggest an inclination towards the void as an explanatory principle.

The last question, in which the void is discussed and to which I want to draw attention to in this paper, is the **seventh question on physical problems**. Since the philosophical content is rather limited, this can be done very briefly. Al-Bīrūnī raises the problem of why a flask shatters when it is filled with water and then freezes. In his answer, Avicenna again refers to the impossibility of void. The water in the flask freezes and contracts, resulting in a virtually empty space between the contracting water and the sealed flask. Because this is impossible, the flask shatters. With this question, al-Bīrūnī seems to have entrapped

---

[45] A nice parallel can be found in Simplicius' commentary on *Phys.*: "That, then, is Aristotle's treatment of the void. But Strato of Lampsacus tries to prove the existence of a void that separates all body, so that it is not continuous, saying that neither light, nor warmth, nor any other bodily power would be able to make its way through water or air or any other body. For how would the rays of the sun make their way to the bottom of a container? For if the wet did not contain ducts, but the rays forced their way through to it, the contents of the containers would come to overflow, and some of the rays would not be reflected in the upper part, while some made their way to the bottom. But I think it is possible to solve these problems in accordance with the Peripatetic hypotheses, according to which warmth and other bodily powers, and light, not being bodies, do not need a void interval as a support of their being and a passage way, but subsist in bodies without increasing their volume." Simplicius, *In Aristotelis physicorum libros quattuor priores commentaria*, ed. by Hermann Diels, CAG, vol. 9 (Berlin, 1882), 693,10–22; cf. James O. Urmson, *Simplicius: On Aristotle On the Void* (London: Bloomsbury, 2013), 219. We find here the same two possible solutions offered by al-Bīrūnī, the first one (the existence of void spaces) is ascribed to Strato, the second one (light as non-bodily subsists in the air) is offered by Simplicius himself. Of course, it is at least highly doubted whether the Arabs were familiar with Simplicius' commentary on *De caelo* and *Physics*, cf. Francis E. Peters, *Aristoteles Arabus: The Oriental Translations and Commentaries on the Aristotelian Corpus* (Leiden: Brill, 1968), 30–4. Against this argues e.g. Michael Chase. Cf. Michael Chase, "Philoponus' Cosmology in the Arabic Tradition," *Recherches de Théologie et Philosophie Médiévales* 79 (2012): 271–306, esp. 292–3. However, it might be interesting to highlight that Strato is reported to have argued for the existence of microvoid spaces without being an atomist. Cf. Furley, *Cosmic Problems*, ch. 13, and Kirk R. Sanders, "Strato on Microvoid," in *Strato of Lampsacus: Text, Translation, and Discussion*, ed. by Marie-Laurence Desclos and William W. Fortenbaugh (New Brunswick, New Jersey: Transaction Publishers, 2011), 263–76. This could become important for an investigation of al-Bīrūnī's attitude towards atomism.

Avicenna. He anticipates Avicenna's and ripostes, noting that the flask shatters outwards, not inwards as we would expect it if we assume the impossibility of void to be the reason for the breaking of the flask.[46]

4 Existence of Void in al-Bīrūnī's *India*

The questions and replies that al-Bīrūnī develops in the correspondence with Avicenna seem to suggest that he is defending the existence of void. He never accepts the peripatetic arguments adduced by Avicenna to defend Aristotle's doctrine of the non-existence of void. Furthermore, he draws from the various arguments employed by the ancient atomists on the one hand and by the Baṣrian Muʿtazilites on the other hand. The main problem with this investigation, however, is that al-Bīrūnī does not give us a specific insight into his own doctrines but instead only raises doubts about different Aristotelian teachings. Therefore, it is also possible that al-Bīrūnī has not come to a final decision on this question. He may simply be unconvinced by these peripatetic arguments and expresses his doubts in the letters to Avicenna. Galen employs this approach to the problem of the existence of void in his *On demonstration*, for example, a work which al-Bīrūnī cites in his *India* in a different context.[47] But Galen is only unsettled concerning the existence of extracosmic void. It is striking, that al-Bīrūnī articulates the same concern in his *India* when he treats the question of what is behind the last sphere:

> The followers of Āryabhaṭa[48] say: "It is sufficient for us to know the space which is reached by the solar rays. We do not need the space, which is

---

[46] The question and answer can be found at Ibn Sīnā and al-Bīrūnī, *As'ila*, 48,8–49,4, and al-Bīrūnī's reply at 58,11–13. The argument by Avicenna can be found in the inner-Muʿtazilite discussions, as well, as it has been put forward by the Baġdādī branch. Cf. Dhanani, *The Physical Theory*, 81.

[47] al-Bīrūnī, *Kitāb fī Taḥqīq mā li-l-hind min maqūla maqbūla fī l-ʿaql aw marḏūla* (Hyderabad: Dā'irat al-maʿārif al-ʿuṯmāniyya, 1958), 74,11; cf. transl. by Eduard Sachau, *Alberuni's India*, vol. 1 (London: Kegan Paul, Trench, Trübner & Co, 1910), 97. For recent studies on this work, cf. Riccardo Chiaradonna, "Le traité de Galien *Sur la démonstration* et sa postérité tardo-antique," in *Physics and philosophy of Nature in Greek Neoplatonism: Proceedings of the European Science Foundation Exploratory Workshop* (*Il Ciocco, Castelvecchio Pascoli, June 22–24, 2006*), ed. by Riccardo Chiaradonna and Franco Trabattoni (Leiden: Brill, 2009), 43–78, and Peter Adamson, "Galen on Void," in *Philosophical Themes in Galen*, ed. by Peter Adamson, Rotraud Hansberger and James Wilberding (London: Institute of Classical Studies, 2014), 197–211.

[48] Indian astronomer (d. 6th century AD), whom al-Bīrūnī often cites in his astronomical

> not reached by the perception of the senses, though it be in itself of an enormous extent. That which is not reached by the rays is not reached by the perception of the senses, and that which is not reached by perception is not knowable." [...] Finally, there are other people who maintain that behind the last limit of motion there is an infinite vacuum, or they deny a vacuum and a plenum. [...] The truth is entirely with the followers of Āryabhaṭa who are like people coming to a judgment in a true sense (*aṣḥāb al-iǧtihād ḥaqqan*).[49]

This passage is of special interest to us for two reasons. The first, and more obvious, is that al-Bīrūnī himself mentions the possible existence of void outside our cosmos. This was a famous Stoic position. Against it, already Aristotle has argued that there is nothing, neither vacuum nor a body.[50] So al-Bīrūnī rehearses two ancient positions, only to conclude that one cannot make a final decision on the question of what is outside of the last sphere. This passage then might provide us with evidence for the hypothesis that al-Bīrūnī could have the same general agnosticism towards void, not only extracosmic void. This would align nicely with the passage, previously discussed, on the clepsydra from the *Chronology*. However, one might challenge this interpretation, claiming that al-Bīrūnī quotes Āryabhaṭa's doctrine in a way that suggests that knowledge is only unattainable of those things that escape sense perception. This doctrine does not apply, however, to the various experiments with the flasks. These experiments are of a clear physical nature and, although they might be difficult to explain, are not comparable to an examination of something that exists outside of the realm of our senses. Thus, it is not certain that his agnosticism towards extracosmic void would also apply to intracosmic void. However, this passage cited above provides us with an indication of his own answer to the question I want to address in what follows.

5 Plurality of Worlds

This is the second reason why this passage is of special interest for us. His agnosticism regarding the existence of anything outside of our cosmos, of course,

---

works. For example, he discusses his theory of the rotating earth (cf. Shlomo Pines, "La théorie de la rotation de la terre á l'époque d'al-Biruni," *Journal Asiatique* 244 (1956): 301–5), but on this question al-Bīrūnī defends the Aristotelian and Ptolemaic system.

[49] Al-Bīrūnī, *Kitāb fī Taḥqīq mā li-l-hind*, 183–55, transl. by Sachau, *Alberuni's India*, 225–7.

[50] E.g. *De caelo* 1.9, 279a6–18.

also applies to the existence of another world. If we cannot be sure of what is outside of our cosmos in general, then it follows that we cannot be sure of the existence of other worlds, as well. This does not mean that we can exclude the existence of other worlds for certain. We should keep this in mind as a position al-Bīrūnī probably already had when he wrote his fifth question on *De caelo*, where he asks the following:

> Why does Aristotle regard it as repulsive when someone claims that the existence of another world, which is outside of and according to a different nature from this one in which we live, is possible? For we know the nature and the four elements only, after we found them, like a blind man, who has not heard people talking about seeing, is not capable of imagining by himself what the seeing is like or that it is a sense, through which colours can be perceived. Or [this other world] is according to a similar nature, but it is created inasmuch as its directions of its movements are different from ours, whereas each of these worlds is separated by a barrier (*barzaḫ*). [It is the same,] like if there is a [triangle] ABC forming a hill on the earth, whereas A and C are closer to the surface than B and water flows from B to A and[51] C. Both are opposite (*mutaḍādda*) movements to a known place.[52]

Apparently, al-Bīrūnī had problems with the arguments set forth by Aristotle against the plurality of worlds in *De caelo* I.7–9. But he does not refer to a specific argument in his question. He rather seems to ask Avicenna to explain to him the grounds for Aristotle's denial of the existence of other worlds, and proposes two possible conceptions of other worlds. Either another world would be built upon totally different elements, which we neither can grasp nor attain knowledge of. Or it would contain the same elements as ours, but the worlds are separated by a barrier. The Arabic term, *barzaḫ*, should attract our attention since it indicates how we should understand al-Bīrūnī's suggestion. This word is a reminiscence of three *suwar* in the *Qurʾān*: At 23:102 it appears as a separation between the worlds of the living and the dead to keep the dead from wandering in the realm of the living. Here we get the connection to the two worlds proposed by al-Bīrūnī. However, at 25:55 and 55:20 the *barzaḫ* prevents salt and fresh water from mixing. Accordingly, al-Bīrūnī considers his barrier to be an impediment between two worlds, which prevents the elements of the one world from interacting with the elements from the other world. As Carra de Vaux puts it in his entry for the *Encyclopedia of Islam*: "the impediment here is the effect of a law of nature established by God."[53] This expression casts light on how al-Bīrūnī imagines this barrier. It lies within God's omnipotence to posit such a barrier, not to oppose nature, for example the natural movement of the elements, but rather to secure the laws of nature, which He had established in the first place. The example of the triangle, from which water can flow towards the bottom along two different directions, makes clear that al-Bīrūnī is indeed thinking of the elements' movement. His example is water flowing down from a hill. Of course, in this passage, al-Bīrūnī adheres to the Aristotelian doctrine of the water's motion towards the centre. But in the case of a hill, one could imagine this motion towards the one side of the hill or the other. The motions seem to oppose each other, but nevertheless both are directed towards the earth's centre. Accordingly, if the idea of a barrier is granted, al-Bīrūnī maintains that water could flow toward two different centres.[54] This is supposed to be a direct answer to *De caelo* I.8, where Aristotle argues that the known elements cannot be outside of our world naturally. They must be removed by force. Every element can, according to Aristotle, only have one place to which it naturally tends. This and the other Aristotelian arguments, which we are going to address later, are directed against the atomists' belief in an infinite number of worlds, which results from the belief in an infinite number of atoms.[55] Since we mentioned before the familiarity of al-Bīrūnī with the atomists' arguments regarding the void, it warrants mentioning that al-Bīrūnī does not discuss an infinite number of worlds. Rather, he only engages with the possibility of one additional world, though he does not exclude the possibility of others.

---

[51] I read و according to MS Leiden Or. 184, fol. 74^{r},6 instead of أو as in Ibn Sīnā and al-Bīrūnī, *Asʾila*, 20,5.

[52] Ibn Sīnā and al-Bīrūnī, *Asʾila*, 19,9–20,5.

Avicenna's answer is extensive. In order not to lose track of the general structure of his reply, I suggest dividing his answer into three main parts: (1.)[56] Avicenna gives a general introduction to arguments which have been put forward for the existence of other worlds and were already mentioned by Aristotle. This part appears to explain the background for Aristotle's arguments. Avicenna then goes on to discuss the question, and he focuses (2.)[57] on the existence of another world composed of the same elements, and, subsequently, (3.)[58] a world composed of other elements that we cannot grasp or perceive. Since his answer is very detailed and elaborate, I will not present a full translation here, but I will highlight the most important features of the discussion.

---

[53] EI^2, vol. I, 1071–2, from which I took the Qurʾānic *suwar*.

[54] Alessandro Bausani has already examined this question but interprets the example of the triangle in a different way: In another world, the triangle could be turned around so that water does not flow down- but upwards. In this case, it would be unnecessary, as I think, to suggest an example with two points at the bottom, towards which the water flows; one point would suffice. Al-Bīrūnī's point is that even in our world, we could imagine water flowing off into two directions; why not with regard to different centres? Cf. Bausani, "Some Considerations," 83.

[55] For a report on the different fragments cf. James Warren, "Ancient Atomists on the Plurality of Worlds," *The Classical Quarterly* 54 (2004): 354–65, esp. 354–5, fn. 2–4.

[56] Ibn Sīnā and al-Bīrūnī, *Asʾila*, 20,6–21,6.

(1.) This part of his answer is the least detailed. Avicenna reiterates a possible argument for the existence of other worlds, and probably has *De caelo* I.9, 277b27–278a22 in mind. There, he addresses the possible argument that one could distinguish between "this world," i.e. the coming-together of form and matter, and "world in general," i.e. the form. One could argue, as Aristotle says, that it is possible that the form of "world in general" is realized in another matter. Avicenna adds to this the further argument that what is possible regarding the eternal things is necessary. This addition is drawn from *Phys.* III.4, where Aristotle discusses the infinite.[59] Avicenna elaborates more on the refutation of this argument in the cosmological part (*as-Samāʾ wa-l-ʿālam*) of his *Kitāb aš-Šifāʾ*.[60] There we find the Aristotelian counter-argument that the entirety of things is within the outermost sphere.[61] It is at least curious why Avicenna leaves this aspect aside in his answer to al-Bīrūnī, which is very detailed in other respects.

Perhaps even more interesting is Avicenna's introductory claim that, in the *De caelo*, Aristotle talks "not to someone who claims that worlds are not similar in any way to this world, but he replies to someone who makes worlds in which the heavens, earths and elements are in accordance to what is in this world with respect to the kind (*an-nawʿ*) and nature, but different in their individuality (*aš-šaḫṣiyya*)."[62] At first sight, this statement might seem somewhat odd, since Aristotle *does* talk about the possibility of completely different elements in the *De caelo*. Before Aristotle presents his arguments regarding the motion of the elements, he briefly refers to elements different in nature:

---

[57] Ibn Sīnā and al-Bīrūnī, *Asʾila*, 21,6–24,10.

[58] Ibn Sīnā and al-Bīrūnī, *Asʾila*, 24,1–27,8.

[59] At 203b23–30, he connects the infinite with the plurality of worlds, so Avicenna probably leans on exactly this passage.

[60] Ibn Sīnā, *as-Samāʾ wa-l-ʿālam*, in Ibn Sīnā, *Kitāb aš-Šifāʾ, aṭ-Ṭabīʿiyyāt, 2. as-Samāʾ wa-l-ʿālam, al-Kawn wa-l-fasād, al-Afʿāl wa-l-infiʿālāt*, ed. by Maḥmūd Qāsim (Cairo: Dār al-kitāb al-ʿarabi li-ṭ-ṭibāʿa wa-n-našr, 1969), 70–6. For a very recent study of this part of the *Šifāʾ*, cf. Cristina Cerami, "The *De Caelo et Mundo* of Avicenna's *Kitāb al-Šifāʾ*: An overview of its structure, its goal and its polemical background," *Documenti e studi sulla tradizione filisofica medievale* 28 (2017): 273–329. In this article, Cerami also argues that al-Bīrūnī is a possible target of Avicenna's critique against one of his contemporaries for relying on arguments by Philoponus. Cf. esp. 308–12, where she shortly touches on four questions of the correspondence, among these the question on the plurality of worlds, as well.

[61] Ibn Sīnā, *as-Samāʾ wa-l-ʿālam*, 73,14–74,4. Cf. *De caelo* I.9, 279a6–18.

[62] Ibn Sīnā and al-Bīrūnī, *Asʾila*, 20,8–10.

> Further, all the worlds must be composed of the same bodies, being similar in nature. But at the same time each of these bodies must have the same potentialities, fire, that is to say, and earth, and the bodies intermediate between them; for if the bodies of another world resemble our own in name only, and not in virtue of having the same form, then it would only be in name that the whole which they compose could be pronounced a world.[63]

Contrary to what Avicenna writes, Aristotle does speak about elements of another world which are different in nature. But upon further investigation of the Aristotelian passage, Avicenna's report might not be as false as it first appears. For Aristotle does not intend to give a detailed argument addressing why there cannot be another world at all. Rather, he merely claims that, in this case, we would not be able to call it a "world." He uses this brief remark only to justify his further claim that earth always tends to move towards the centre of our cosmos, and that there cannot be "another earth" with a different nature. This is probably the reason for Avicenna's suggestion that Aristotle does not address this question in the *De caelo*, and it explains why he looks for other possible grounds to deny the existence of different elements in other works.

(2.) We have already touched on the way in which Aristotle tries to disprove the existence of another world: Since earth, for example, tends to move towards the centre of this world, the earth of another world would have the same natural tendency and therefore could only be held back by constraint in an unnatural place. However, it is impossible for elements to form another world naturally.[64] In his long passage, Avicenna supplements this argument with the claim that what is by constraint (*bi-l-qasr*) cannot be eternal. Therefore, the other elements cannot form another world by constraint eternally. Lastly, if the elements were held by constraint outside of their natural position, this position would have to be natural for another body, which is impossible as well, since everything is within our cosmos.[65] Avicenna here follows the Aristotelian text. However, he omits one further argument from the *Metaphysics*

---

[63] *De caelo* 1.8, 276a31–b4, transl. by William Keith Chambers Guthrie, *Aristotle On the Heavens* (Cambridge, Mass.: Harvard University Press, 1939).

[64] *De caelo* 1.8, 276a27–b21.

[65] *De caelo* 1.8, 277b14–22 and 1.9, 278b25–279a6.

This content downloaded from 131.111.5.135 on Tue, 11 Jun 2024 09:03:32 +00:00

that Aristotle refers to in the *De caelo*. At *Met.* XII.8, 107a31–38 Aristotle shows that the existence of another eternal moving sphere would make another First Mover necessary. But there can only be one First Mover.[66]

Avicenna does not refute, or even engage with al-Bīrūnī's suggestion of a *barzaẖ*. This may be a reason why al-Bīrūnī is not ultimately convinced by Avicenna's explanations, since Avicenna simply rehearses the Aristotelian argument. As stated before, al-Bīrūnī probably does not dispute his arguments regarding the movement of the elements. He introduces, however, this *barzaẖ*, on the one hand, to allow the creation of another world, which should be possible due to God's omnipotence, and on the other hand, to secure the physical foundations set by Aristotle. His acceptance of the Aristotelian doctrine of natural places becomes evident through al-Bīrūnī's example concerning the triangle. He does not want the water to have a downward *and* an upward motion naturally at the same time. Rather, both movements proceed towards the centre of the earth, but just in two different directions. To extend this example to the case of two different worlds, one would need the barrier. Nevertheless, al-Bīrūnī obviously shifts the terms of debate by insisting on God's omnipotence. In his reply to Avicenna, he defends this as follows: "For who creates two distinct earths and fires, is capable of creating for each of them an up and down."[67]

(3.) This last, similarly exhaustive part is by far the most interesting feature of Avicenna's answer. Avicenna borrows material from *De anima*, in order to object to the suggestion made by al-Bīrūnī that the existence of elements which we cannot conceive is at least possible. This then tells us why Avicenna wrote at (1.) that Aristotle does not engage with this question in the *De caelo*. He apparently thinks that Aristotle's cosmology only provides us with a rejection of the existence of other worlds composed of the same elements. The existence of different elements can only be refuted by means of his psychological doctrines. The core of his argument can be summarized very briefly. Avicenna aims to prove that there cannot be qualities that the human being is not able to grasp. He presents the hierarchy of souls of plants, animals, and humans and claims that "nature" (*aṭ-ṭabīʿa*), as he puts it, cannot enter a higher rank without being equipped with every property from the lower ranks. This means that to enter the highest rank, the rational, one needs every perceiving power from the lower ranks. Since humans, as the highest intellectual beings, are born with the "rational substance" (*ǧawhar nāṭiq*), they are able to perceive everything. Therefore there is nothing which humans cannot grasp.

---

[66] Aristotle's reference can be found at *De caelo* I.8, 277b9–12. It is unfortunate that Avicenna does not include Aristotle's further reference in his answer to al-Bīrūnī.

[67] Ibn Sīnā and al-Bīrūnī, *As'ila*, 54,2–4.

As a source, he refers to the third book of *De anima* and to commentators such as Themistius and Alexander. In the *De anima*, there are some indications in this direction, but Aristotle does not make the connection to the existence of things that are composed of a nature that we cannot grasp and outside of our cosmos.[68] This connection between the *De caelo* and the *De anima* seems to be unique. It is, at least to my knowledge, not found in any other discussion, neither on the plurality of worlds nor on the perceptive power of the souls, and neither in the Greek nor in the Arabic tradition. The fact that Avicenna does not mention this argument later in his afore-mentioned own cosmological treatise within the *Kitāb aš-Šifāʾ* can be explained by the fact that this is supposed to be his own version of the *De caelo*, and not the *De anima*. Therefore, it is useful that Avicenna provides us with the information that he used the commentaries by Themistius and Alexander (of which the latter is lost[69]). In his comments on *De anima* III.1, 425a9–13, Themistius presents the following argument, which Avicenna probably had in mind:

> So if there is no other body beyond the four elements and their compounds (and these are all the bodies in this world [literally: here][70]), and if these bodies have no quality beyond these that they are currently thought to have, then there is no sense that animals are missing. Obviously nature always provides less developed capacities in advance as a complete support for more developed ones, so that a person with reason and intellect would already possess all the senses.[71]

This is the only evidence of a possible source for Avicenna.[72] Themistius, as well, touches on the problem of the existence of a body that is formed by other elements, and connects it with the Aristotelian passage in *De anima*. This commentary contains all of the important aspects of Avicenna's answer: his claims that there are no bodies according to other elements, that all bodies exist within our world, and finally that there are no qualities within these bodies which we cannot perceive.

---

[68] Cf. *De anima* III.1, 425a9–13, but also II.3, 414b32–415a11, III.4, 429a18–20 and III.12, 434a30–b2.

[69] Cf. Peters, *Aristoteles Arabus*, 43. In Alexander's tractate *De anima* only appears the remark, that without touch there cannot be other perceiving faculties, cf. Alexander of Aphrodisias, *De anima libri mantissa: a new edition of the Greek text*, ed. by Robert W. Sharples (Berlin: De Gruyter, 2008), 40,11–15.

[70] Literally *entautha*. Cf. the translator's footnote 8 on p. 180.

[71] Themistius, *In libros Aristotelis de anima paraphrasis*, ed. by Richard Heinze, CAG, vol. 5.3 (Berlin: Georg Reimer, 1899), 81,11–18, transl. by Robert B. Todd (Ithaca, New York: Bloomsbury, 1996), 103.

[72] At least a loose similarity can be found in Plotinus' *Enneads*. In the fourth *Ennead*, Plotinus suggests, in the chapter about seeing, a thought experiment. Could an eye, which is located on the "back of the heavens," see a second cosmos? He later comes to the conclusion that the perception of this other world was not possible, since there would be no connection with ours; this other world would have other qualities than ours. But

However, this seems to be the only parallel account before or after Avicenna. An explanation for this lack of similar accounts might be, at least in the case of the Arabic tradition, the fact that the question of the plurality of worlds was apparently not an issue that was discussed very often before 1000 AD, i.e. before the letter exchange. There is no evidence that it was debated in *falsafa*. Of course, one could argue that, for example, al-Kindī would have argued against the plurality of worlds, since he follows Aristotle in claiming that there is nothing outside of our cosmos.[73] One could imagine that he did not deviate from the Neoplatonic tradition, since Proclus and Philoponus denied the plurality of worlds.[74] However, the Neoplatonists addressed this question in their works, whereas in *falsafa* this topic does not come up until al-Bīrūnī's question to Avicenna and Avicenna's paraphrase of the *De caelo* in the *Kitāb aš-Šifāʾ*.[75] Al-Bīrūnī's reply may provide us with a clue to the history of this question in the Arabic theological tradition, *kalām*. After claiming that it should be possible for God to create two earths with different centres of their movements, he writes: "If you do not admit this, then I do not admit, that the movements from the centre to the outside are equal movements of one kind, and I say with the Baṣrians: …"[76] Here the reply is interrupted, and the compiler (who, as we should remember, was a member of the Avicennan circle) writes: "And he [viz. al-Bīrūnī] says with respect to the end of the answer to the question in

---

his thought experiment is in a different context than in al-Bīrūnī's question: Plotinus discusses mainly the perception of the soul. For Plotinus, the existence of other worlds is absurd. Cf. Plotinus, *Plotini Opera II. Enneades IV–V*, ed. by Paul Henry and Hans-Rudolf Schwyzer (Paris, Brussels: Desclée de Brouwer, 1959), IV.5.3, 22–26 and IV.5.8. Anyway, this part of the Enneads was not part of the so-called *Theology of Aristotle*.

[73] Cf. Peter Adamson, *Al-Kindī* (Oxford: University Press, 2007), 181–2.

[74] Proclus, *Procli Diadochi in Platonis Timaeum commentaria*, ed. by Ernst Diehl, 3 vols (Leipzig: Teubner, 1903–06), II, 65–7; Philoponus, *De opificio mundi. Über die Erschaffung der Welt* [Greek-German], introd. and transl. into German by Clemens Scholten (Freiburg: Herder, 1997), III.3, 285 and III.9, 309.

[75] A reason might be the fact that the Neoplatonic tradition was heavily concerned with Plato's account from the *Timaeus* (31a and 55c4–d6). Through Galen's paraphrase, only one sentence on this question was transmitted into Arabic, cf. Paul Kraus and Richard Walzer (eds.), *Galeni Compendium Timaei Platonis* (London: Warburg Institute, 1951), ch. III, a.

[76] Ibn Sīnā and al-Bīrūnī, *As'ila*, 54,4 f.

objection […].”[77] Sadly, due to the fact that al-Bīrūnī’s answers and replies are not always reported in full, we do not know what al-Bīrūnī says about the Baṣrians, by which he probably means the Muʿtazilites from Baṣra. Nevertheless, this draws our attention to the *kalām*-tradition, and indeed, we find one report of importance to our investigation. In his *Kitāb al-Intiṣār*, the Baġdādī Muʿtazilite al-Ḫayyāt (d. 913 AD) reports the teaching of Ibrāhīm an-Naẓẓām (d. 9th century AD), who claims that “God is able to create examples of the world (*amṯāl ad-dunyā*)[78] and images of its image *ad infinitum*,”[79] and that “God creates in one moment (*ḥāl wāḥida*) that, which of the bodies has no end.”[80] Shaky as this report may be, both of these passages are already referred to by Alessandro Bausani in his article on the plurality of worlds in the Islamic tradition. He names in addition al-Bāqillānī (d. 1012), who apparently argues for the plurality of worlds by means of God’s omnipotence.[81] But this seems to exhaust the material on this question in the Arabic tradition before 1000 AD, and this material comes out of the theological tradition on God’s omnipotence. There is no hint of a discussion of the Aristotelian background. This makes al-Bīrūnī’s question even more interesting, since it could be seen as triggering a discussion of this topic in *falsafa*. Al-Bīrūnī’s question could have been the trigger for Avicenna to include this discussion in his *Kitāb aš-Šifāʾ*. Suddenly, after Avicenna, a philosophical debate will arise, as evidenced by the detailed discussion in Faḫr ad-Dīn ar-Rāzī’s works. He, as well, connects doubts on the Peripatetic arguments with his strong emphasis on the omnipotence of God.[82]

6 Conclusion

This last observation is definitely one of the most striking features of the present investigation. It is somewhat strange that the connection between a monotheistic religion with an almighty God and the imagination of an infinite number of worlds due to the infinite power of God was not drawn more often in the Islamic context.[83] The situation might be comparable to that of the Jewish tradition, in which it is difficult to follow the traces of the Aristotelian influence on this question. At least we know that Saʿadia, adopted the Aristotelian denial of other worlds.[84] In addition, the way in which al-Bīrūnī poses his question reveals much of his attitude towards the Aristotelian texts. Of course, the letters might be deemed "anti-aristotelian" because the interrogative style of the text necessitates that al-Bīrūnī only touches upon the aspects of the Aristotelian teachings that he finds objectionable. On the other hand, one should not confuse this with his overall attitude towards Aristotle; in general, his philosophy is not anti-peripatetic. This is evidenced by many passages in other works, for example in his *India*, where he uses Aristotelian arguments to refute some Hindu teachings,[85] as well as by his engagement with this specific question on the plurality of worlds. In response to this problem, he accepts the natural movements of the elements and introduces a barrier created by God to preserve the basic physical foundations of the Aristotelian cosmos.[86]

---

[77] Ibn Sīnā and al-Bīrūnī, *Asʾila*, 54,5 f.

[78] Note, that he does not talking about *ʿālam*.

[79] Al-Ḫayyāt, *Kitāb al-Intiṣār wa-r-radd ʿalā Ibn ar-Rāwandī al-mulḥid*, ed. by Albert N. Nader (Beirut: al-Matbaʿa al-kaṯūlīkiyya, 1957), 44,18–9.

[80] Al-Ḫayyāt, *Kitāb al-Intiṣār*, 46,15–6.

[81] Cf. Alessandro Bausani, “Nizami di Gangia e la Pluralità dei mondi,” *Rivista degli studi orientali* 46 (1971): 197–215.

[82] Faḫr ad-Dīn ar-Rāzī, *al-Maṭālib al-ʿāliya min al-ʿilm al-ilāhī*, ed. by Aḥmad Ḥiǧāzī as-Saqqā, vol. VI (Beirut: Dār al-kitāb al-ʿarabī, 1987), 193–5, and *al-Mabāḥiṯ al-mašriqiyya fī ʿilm al-ilāhiyyāt wa-ṭ-ṭabīʿiyyāt*, ed. by Muḥammad al-Muʿtaṣim bi-llāh al-Baġdādī, vol. II (Beirut: Dār al-kutub al-ʿilmiyya, 1990), 146–150. Cf. ʿAdi Setia, “Fakhr al-Din on Physics and the Nature of the Physical World,” *Islam & Science* 2 (2004): 161–80.

However, in the context of the question of the existence of void, al-Bīrūnī's opinion remains unclear. It is, indeed, possible that he did not even have one. The fact that the problem of the plurality of worlds differs from the question of the existence of void in other respects, such as, for example, the fact that the latter was widely debated among Arabic philosophers, necessitates an investigation of all 18 questions from the letter exchange in order to complete our picture of al-Bīrūnī's philosophical approach. The letters are also illuminating with respect to Avicenna's answers, since they contain some arguments that Avicenna later improved upon, thereby revealing a development in Avicenna's thought. And finally, Avicenna's answers deserve wider recognition, since, regarding the plurality of worlds, for example, he found an elegant and unique way of connecting different arguments from the *De caelo* and the *De anima* to argue against the plurality of worlds.

---

[83] Cf. Bausani, "Nizami di Gangia," 202, and the statement by De Boer in EI^2, vol. I, 349: "[…] nor were the fables of the ancient Greeks about an endless plurality of worlds beside or in succession to one another believed […]."

[84] Cf. Harry A. Wolfson, *The Philosophy of the Kalam* (Cambridge, Massachusetts: Harvard University Press, 1976), 375.

[85] For an example, see his usage of Aristotelian arguments for the First Mover in order to argue against a ninth sphere outside of the sphere of the fixed stars in al-Bīrūnī, *Kitāb fī Taḥqīq mā li-l-hind*, 183–4, transl. by Sachau, *Alberuni's India*, 223–7.

[86] This is different from Bausani's interpretation. He writes: "Here we notice the basic reason for his openness towards 'infinite possibilities:' his simple faith in the Qur'ānic God, unadulterated by theological and metaphysical speculations." Cf. Bausani, "Some Considerations," 84.

Acknowledgements

In this paper, I present some of the results from my Master's thesis. Thus, I am grateful to my two supervisors Peter Adamson and Rotraud Hansberger for their ongoing support and helpful comments on my translations. An earlier version of this paper was presented at a graduate workshop in Pisa, 6th–7th October 2017, organised by Amos Bertolacci. I am grateful to all participants for a fruitful discussion on my talk. Finally, I am also grateful to the anonymous reviewer for helpful remarks and corrections.

Bibliography

Manuscript Sources

Avicenna and al-Bīrūnī. *Risāla li-š-Šayḫ ar-raʾīs Abī ʿAlī l-Husayn ibn ʿAbd Allāh ibn Sīnā ilā Abī r-Rayḥān Muḥammad ibn Aḥmad al-Bīrūnī fī ǧawāb masāʾil anfaḏahā ilayhi min Ḫwārizm*. MS, Leiden, University, Or. 184, fols. 65^{v}–86^{v} (dated 515 AH).

Printed Sources

Adamson, Peter. *Al-Kindī*. Oxford: University Press, 2007.

Adamson, Peter. "Galen on Void." In *Philosophical Themes in Galen*. Ed. by Peter Adamson, Rotraud Hansberger and James Wilberding. London: Institute of Classical Studies, 2014, 197–211.

Alexander of Aphrodisias. *De anima libri mantissa: a new edition of the Greek text*. Ed. by Robert W. Sharples. Berlin: De Gruyter, 2008.

Argyrakis, Vaios. "The clepsydra experiment, clepsydra's functioning and the related devices in Heron's *Pneumatics*." *Almagest* 2 (2011): 16–27.

Bausani, Alessandro. "Nizami di Gangia e la Pluralità dei mondi." *Rivista degli studi orientali* 46 (1971): 197–215.

Bausani, Alessandro. "Some Considerations on Three Problems of the Anti-Aristotelian Controversy between al-Biruni and Ibn Sina." In *Akten des VII. Kongresses für Arabistik und Islamwissenschaft*. Ed. by Albert Dietrich. Göttingen: Vandenhoeck & Ruprecht, 1976, 74–85.

Berjak, Rafik and Muzaffar Iqbal. "Ibn Sīnā—Al-Bīrūnī Correspondence." *Islam & Science* 1–5 (2003–07) (published in eight parts).

Berryman, Sylvia. *The Mechanical Hypothesis in Ancient Greek Natural Philosophy*. Cambridge: University Press, 2009.

al-Bīrūnī. *Kitāb al-Āṯār al-bāqiyya ʿan al-qurūn al-ḫāliyya*. Ed. by Eduard Sachau. Leipzig: Brockhaus, 1878. Transl.: Eduard Sachau. *The Chronology of Ancient Nations*. London: William H. Allen and Co., 1879.

al-Bīrūnī. *Kitāb fī Taḥqīq mā li-l-hind min maqūla maqbūla fī l-ʿaql aw marḏūla*. Hyderabad: Dāʾirat al-maʿārif al-ʿuṯmāniyya, 1958. Transl.: Eduard Sachau. *Alberuni's India*, 2 vols. London: Kegan Paul, Trench, Trübner & Co, 1910.

Boilot, Jacques-Dominique. "L' oeuvre d' al-Beruni. Essai Bibliographique." *Mélanges de l'Institut dominicain d'études orientales* 2 (1955): 161–396.

Cerami, Cristina. "The *De Caelo et Mundo* of Avicenna's *Kitāb al-Šifāʾ*: An overview of its structure, its goal and its polemical background." *Documenti e studi sulla tradizione filisofica medievale* 28 (2017): 273–329.

Chase, Michael. "Philoponus' Cosmology in the Arabic Tradition." *Recherches de Théologie et Philosophie Médiévales* 79 (2012): 271–306.

Chiaradonna, Riccardo. "Le traité de Galien Sur la démonstration et sa postérité tardo-antique." In *Physics and philosophy of Nature in Greek Neoplatonism. Proceedings of the European Science Foundation Exploratory Workshop* (*Il Ciocco, Castelvecchio Pascoli, June 22–24, 2006*). Ed. by Riccardo Chiaradonna and Franco Trabattoni. Leiden: Brill, 2009, 43–78.

Daiber, Hans. "Farabis Abhandlung über das Vakuum." *Der Islam* 60 (1983): 37–47.

Dhanani, Alnoor. *The Physical Theory of Kalām: Atoms, Space, and Void in Basrian Muʿtazilī Cosmology*. Leiden: Brill, 1994.

van Ess, Josef. *Theologie und Gesellschaft im 2. und 3. Jahrhundert Hidschra: Eine Geschichte des religiösen Denkens im frühen Islam*. Berlin: De Gruyter, 1991–97.

al-Fārābī, Abū Naṣr. *Ebû Nasr Il-Fârâbî'nin Halâ Üzerine Makalesi. Fârâbî's Article On Vacuum* [Turkish-English-Arabic]. Ed. and transl. by Necati Lugal and Aydın Sayılı. Ankara: Türk Tarih Kurumu Basımevi 1951.

al-Fārābī, Abū Naṣr. *Risāla fī l-ḫalāʾ*. S. al-Fārābī. *Fârâbî's Article On Vacuum.*

Furley, David. *Cosmic Problems. Essays on Greek and Roman Philosophy of Nature*. Cambridge: University Press, 1989.

Glasner, Ruth. "The Hebrew Version of *De celo et mundo* Attributed to Ibn Sīnā." *Arabic Sciences and Philosophy* 6 (1996): 89–112.

Gutas, Dimitri. *Avicenna and the Aristotelian Tradition: Introduction to Reading Avicenna's Philosophical Works*. 2nd edition. Leiden, Boston: Brill, 2014.

Guthrie, William Keith Chambers. *Aristotle On the Heavens*. Cambridge, Mass.: Harvard University Press, 1939.

al-Ḫayyāt, Abū l-Ḥussayn ibn ʿUṯmān. *Kitāb al-Intiṣār wa-r-radd ʿalā Ibn ar-Rāwandī al-mulḥid*. Ed. by Albert N. Nader. Beirut: al-Matbaʿa al-kaṯūlīkiyya, 1957.

Hasse, Dag Nikolaus. *Avicenna's* De anima *in the Latin West*. London: Warburg Institute, 2000.

Heinen, Anton M. "A Priori Positions Determining al-Biruni's Scientific Work." In *The Scholar and the Saint: Studies in Commemoration of Abu'l-Rayhan al-Bīrūnī and Jalal al-Din al-Rūmī*. Ed. by Peter J. Chelkowski. New York: University Press, 1975, 54–6.

Ibn Sīnā, Abū ʿAlī. *as-Samāʾ wa-l-ʿālam*. In *Kitāb aš-Šifāʾ, aṭ-Ṭabīʿiyyāt, 2. as-Samāʾ wa-l-ʿālam, al-Kawn wa-l-fasād, al-Afʿāl wa-l-infiʿālāt*. Ed. by Maḥmūd Qāsim. Cairo: Dār al-kitāb al-ʿarabī li-ṭ-ṭibāʿa wa-n-našr, 1969, 70–6.

Ibn Sīnā, Abū ʿAlī. *as-Samāʿ aṭ-ṭabīʿī*. In *The Physics of the Healing: A parallel English-Arabic text translated, introduced, and annotated by Jon McGinnis*. Provo, Utah: Brigham Young University Press, 2009.

Ibn Sīnā, Abū ʿAlī and Abū r-Rayḥān al-Bīrūnī. *Asʾila*. S. Ibn Sīnā and al-Bīrūnī, *al-Asʾilah waʾl-Ajwibah*

Ibn Sīnā, Abū ʿAlī and Abū r-Rayḥān al-Bīrūnī. *al-Asʾilah waʾl-Ajwibah* (*Questions and Answers*). *Including the further answers of al-Bīrūnī and al-Maʿsūmī's defense of Ibn Sīnā*. Ed. by Seyyed Hossein Nasr and Mahdi Mohaghegh. Tehran: High Council of Culture and Art, 1973.

Ibn Sīnā, Abū ʿAlī and Abū r-Rayḥān al-Bīrūnī. "Beyrunî'nin Ibn-i Sinâ'ya Yönelttiği Bazı Sorular, Ibn-i Sinâ'nın Cevapları ve Bu Cevaplara Beyrunî'nin Itirazları." Ed. by Muhammed Tancî. In *Beyrunî'ye Armağan* Ankara: Türk Tarih Kurumu Basımevi, 1974, 231–301.

Kozah, Mario. *The Birth of Indology as an Islamic Science: Al-Biruni's Treatise on Yoga Psychology*. Leiden: Brill, 2016.

Kraus, Paul (ed.). *Épître de Bērūnī, contenant le répertoire des ouvrages de Muḥammad B. Zakarīyā ar-Rāzī*. Paris: Impr. Orientaliste au Calame, 1936.

Kraus, Paul and Richard Walzer (eds.). *Galeni Compendium Timaei Platonis*. London: Warburg Institute, 1951.

Lettinck, Paul. *Aristotle's Meteorology and its Reception in the Arab World: With an Edition and Translation of Ibn Suwār's Treatise on Meteorological Phenomena and Ibn Bajja's Commentary on the Meteorology*. Leiden, Boston, Cologne: Brill, 1999.

Meyerhof, Max. "ʿAli al-Bayhaqī's Tatimmat Siwān al-Hikma: A Biographical Work on Learned Men of the Islam." *Osiris* 8 (1948): 122–217.

Mishra, J.S. "New Light on Albiruni's Stay and Travel in India." *Central Asiatic Journal* 15 (1972): 302–12.

Müller, Ian. *Simplicius: On Aristotle On the Heavens*. S. Simplicius. *In Aristotelis de caelo commentaria*.

Nasr, Seyyed Hossein. *An Introduction to Islamic Cosmological Doctrines*. Revised edition. Albany: Thames and Hudson, 1993.

Peters, Francis E. *Aristoteles Arabus: The Oriental Translations and Commentaries on the Aristotelian Corpus*. Leiden: Brill, 1968.

Philoponus. *In Aristotelis physicorum libros quinque posteriores commentaria*. Ed. by Girolamo Vitelli. CAG, vol. 17. Berlin: Georg Reimer, 1888.

Philoponus. *De opificio mundi. Über die Erschaffung der Welt* [Greek-German]. Introd. and transl. into German by Clemens Scholten, 3 vols. Freiburg: Herder, 1997.

Pines, Shlomo. *Beiträge zur islamischen Atomenlehre*. Berlin: A. Heine, 1936.

Pines, Shlomo. "La théorie de la rotation de la terre á l' époque d' al-Biruni." *Journal Asiatique* 244 (1956): 301–5.

Plotinus. *Plotini Opera II. Enneades IV–V*. Ed. by Paul Henry and Hans-Rudolf Schwyzer. Paris, Brussels: Desclée de Brouwer, 1959.

Proclus. *Procli Diadochi in Platonis Timaeum commentaria*. Ed. by Ernst Diehl, 3 vols. Leipzig: Teubner, 1903–06.

ar-Rāzī, Faḫr al-Dīn. *al-Maṭālib al-ʿāliya min al-ʿilm al-ilāhī*. Ed. by Aḥmad Ḥiǧāzī as-Saqqā, 9 vols. Beirut: Dār al-kitāb al-ʿarabī, 1987.

ar-Rāzī, Faḫr al-Dīn. *al-Mabāḥiṯ al-mašriqiyya fī ʿilm al-ilāhiyyāt wa-ṭ-ṭabīʿiyyāt*. Ed. by Muḥammad al-Muʿtaṣim bi-llāh al-Baġdādī, 2 vols. Beirut: Dār al-kutub al-ʿilmiyya, 1990.

Sachau, Eduard. *The Chronology of Ancient Nations*. S. al-Bīrūnī. *al-Āṯār*.

Sachau, Eduard. *Alberuni's India*. S. al-Bīrūnī. *Kitāb fī Taḥqīq mā li-l-hind*.

Sanders, Kirk R. "Strato on Microvoid." In *Strato of Lampsacus: Text, Translation, and Discussion*. Ed. by Marie-Laurence Desclos and William W. Fortenbaugh. New Brunswick, New Jersey: Transaction Publishers, 2011, 263–76.

Setia, ʿAdi. "Fakhr al-Din on Physics and the Nature of the Physical World." *Islam & Science* 2 (2004): 161–80.

Simplicius. *In Aristotelis de caelo commentaria*. Ed. by Johan L. Heiberg. CAG, vol. 7. Berlin: Georg Reimer, 1894. Transl.: Ian Müller. *Simplicius: On Aristotle On the Heavens*. Ythaca, New York: Cornell University Press, 2004.

Simplicius. *In Aristotelis physicorum libros quattuor priores commentaria*. CAG, vol. 9. Ed. by Hermann Diels. Berlin: Georg Reimer, 1882. Transl.: James O. Urmson. *Simplicius: On Aristotle On the Void*. London: Bloomsbury, 2013.

Rosenfeld, Boris A. and Ekmeleddin Ihsanoğlu. *Mathematicians, Astronomers, and other Scholars of Islamic Civilization and their Works (7th–19th c.)*. Istanbul: Research Center for Islamic History, Art and Culture, 2003.

Ruska, Julius. "Al-Biruni als Quelle für das Leben und die Schriften al-Razi's." *Isis* 5 (1923): 26–50.

Sorabji, Richard. *Matter, Space and Motion: Theories in Antiquity and Their Sequel*. London: Duckworth, 1988.

Strohmaier, Gotthard. *Al-Bīrūnī. In den Gärten der Wissenschaft. Ausgewählte Texte aus den Werken des muslimischen Universalgelehrten*. Second edition. Leipzig: Reclam, 2002.

Strohmaier, Gotthard. *Avicenna*. Munich: C.H. Beck, 2006.

Themistius. *In libros Aristotelis de anima paraphrasis*. Ed. by Richard Heinze. CAG, vol. 5.3. Berlin: Georg Reimer, 1899. Transl.: Robert B. Todd. *Themistius: On Aristotle On the Soul*. London: Bloomsbury, 2013.

Todd, Robert B. *Themistius: On Aristotle On the Soul*. S. Themistius. *In de anima*.

Urmson, James O. *Simplicius: On Aristotle On the Void*. S. Simplicius. *In phys*.

de Vaux, Carra. "barzaḫ." In *Encyclopaedia of Islam*. Second Edition. Leiden: Brill, 1986–2004, vol. I, 1071–2.

Warren, James. "Ancient Atomists on the Plurality of Worlds." *The Classical Quarterly* 54 (2004): 354–65.

Wolfson, Harry A. *The Philosophy of the Kalam*. Cambridge, Massachusetts: Harvard University Press, 1976.